PUMA Test Program

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Introduction

Overall Objectives of PUMA Project

- Generation of Well Scaled
  - Integral Test Data
  - Separate Effects Test Data

  for Advanced BWR Designs with Passive Safety Features
- Benchmarking of NRC Safety Analysis Code (TRACE) with Above
- Major Applications
  - Design Certification of Advanced BWRs
  - NRC Advanced Code (TRACE) Verification
  - Evaluation of Beyond Design Basis Accidents
  - Operational Transient Evaluation
    - Start-up Transient (Nuclear Coupled Simulation)

Introduction
NRC General Requirements for PUMA

- Important Safety Issues to be Addressed

  1) Core Uncovery and Core Damage in a LOCA or Other Transients
     - Effectiveness of GDCS (ECCS)

  2) Containment Integrity
     - Effectiveness of Suppression Pool, PCCS & ICS

  3) System Interactions (Safety & Non-safety),
     Condensation Water Hammer

  4) Effect of Multiple Failure of Safety Systems and Safety Margin

- Simulation of All Key Components, Safety Systems and Phenomena
- Sufficient Instrumentation and Reliable QA Procedure

Past PUMA Project

- PUMA Scaling, Design and Construction
- Integral Tests for DBA of SBWR
- Separate Effects Tests
  - Single-Phase & Two-Phase Natural Circulation
  - Low Pressure Critical Flow
  - Start-up Transients (Nuclear Coupled)
  - PCCS (Blowdown, Cyclic & Long Term Cooling)
  - SP Condensation, Mixing and Stratification
- Integral Tests for Evaluation of Early Advanced BWR Design (Partial Simulation)
  - GDCS in SP
  - PCCS Drain into RPV
- TRACE Code Assessments

PUMA Scaling Method

- Physical Principles

  Conservation Equations

  Constitutive Laws

  Phenomenological Models

- Scaling Principles

Similar Systems $\leftrightarrow$ Scaled Equations be Same $\downarrow$ Scaling Criteria

- Basic Approach

  Top Down, Level 1

    Mass and Energy Balance for Each Component

    Intercomponent Flow Simulation

  Top Down, Level 2

    1-D Drift Flux Model for Each Loop for Transient Response

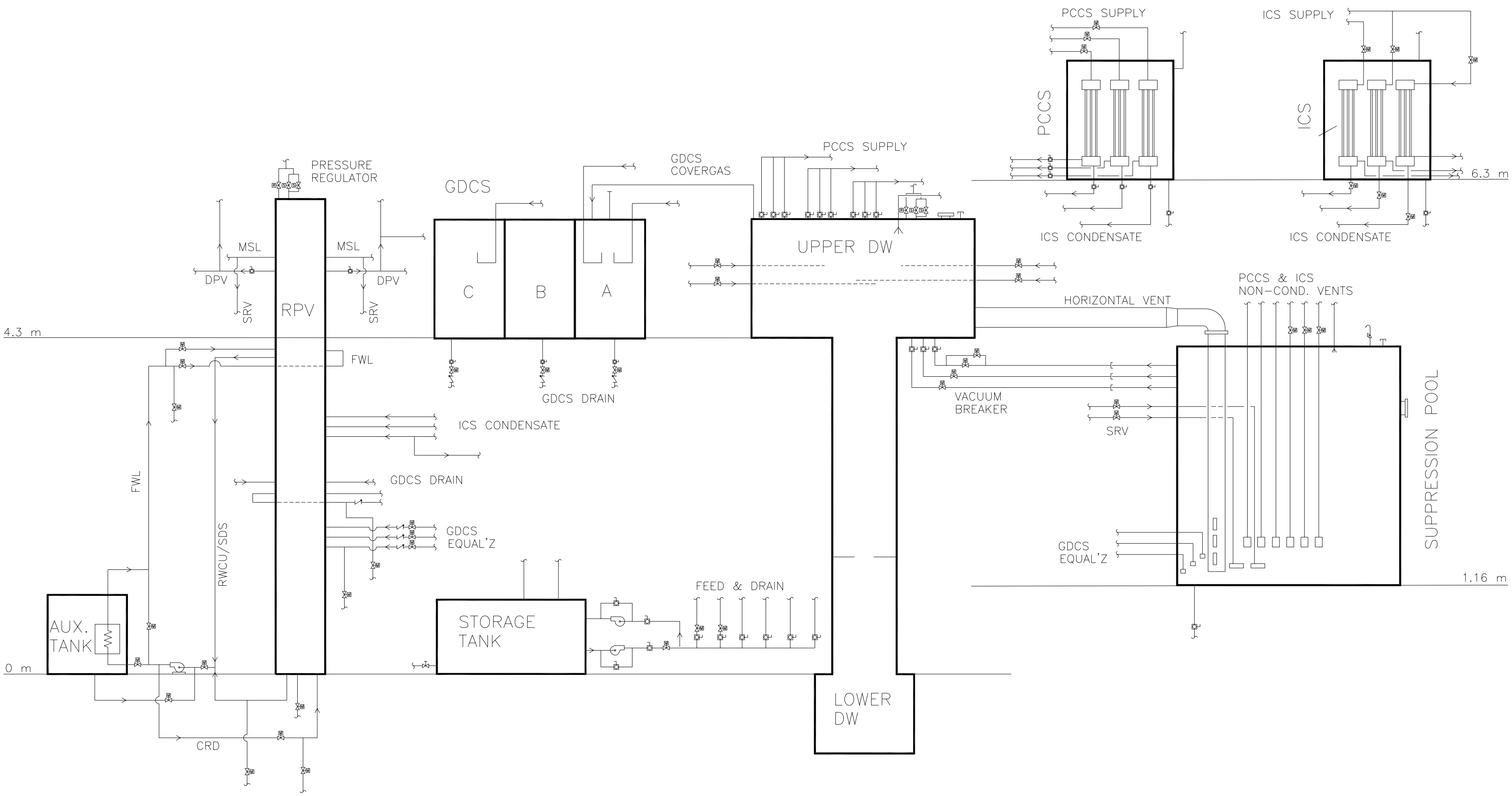
    Mass, Energy and Flow Distribution Simulation

  Local Phenomena Scaling

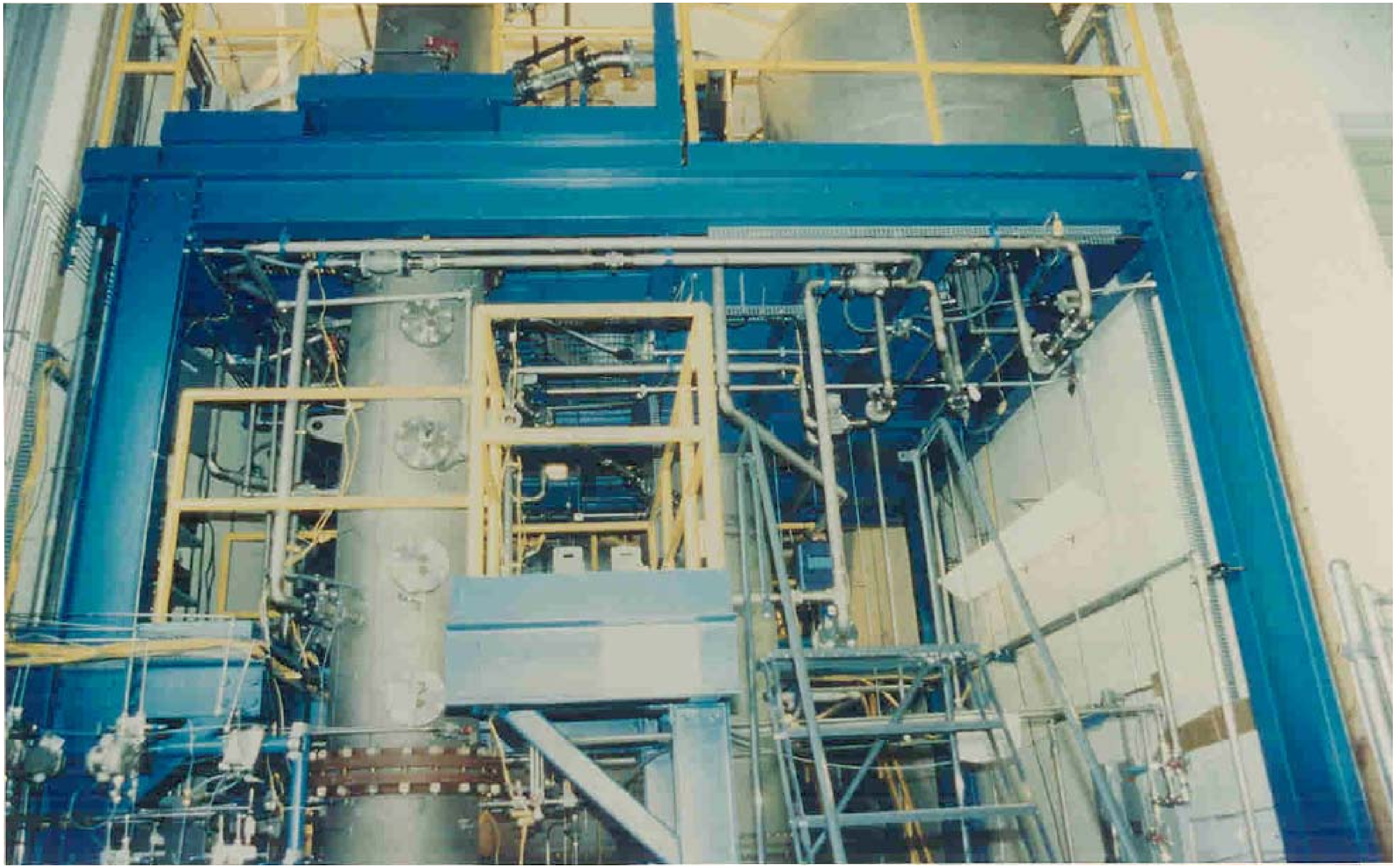
PUMA Design Description

- Pressure: Full Pressure
  Transients below 150 psi
- Volume: ~ 1/400
- Height: ~ 1/4
- Separate Vessel Component Design
  - RPV
  - Drywell
  - Wetwell
  - Gravity Driven Cooling System (GDCS)
  - Simplified ADS System (SRV & DPV)
  - PCCS (3 units)
  - ICS (3 units)
- Aspect Ratio Scale: 1/2.5
- Power: Electrical Heater Rods (~ 40)
  450 kW max.
  For 2% or less of full power simulation

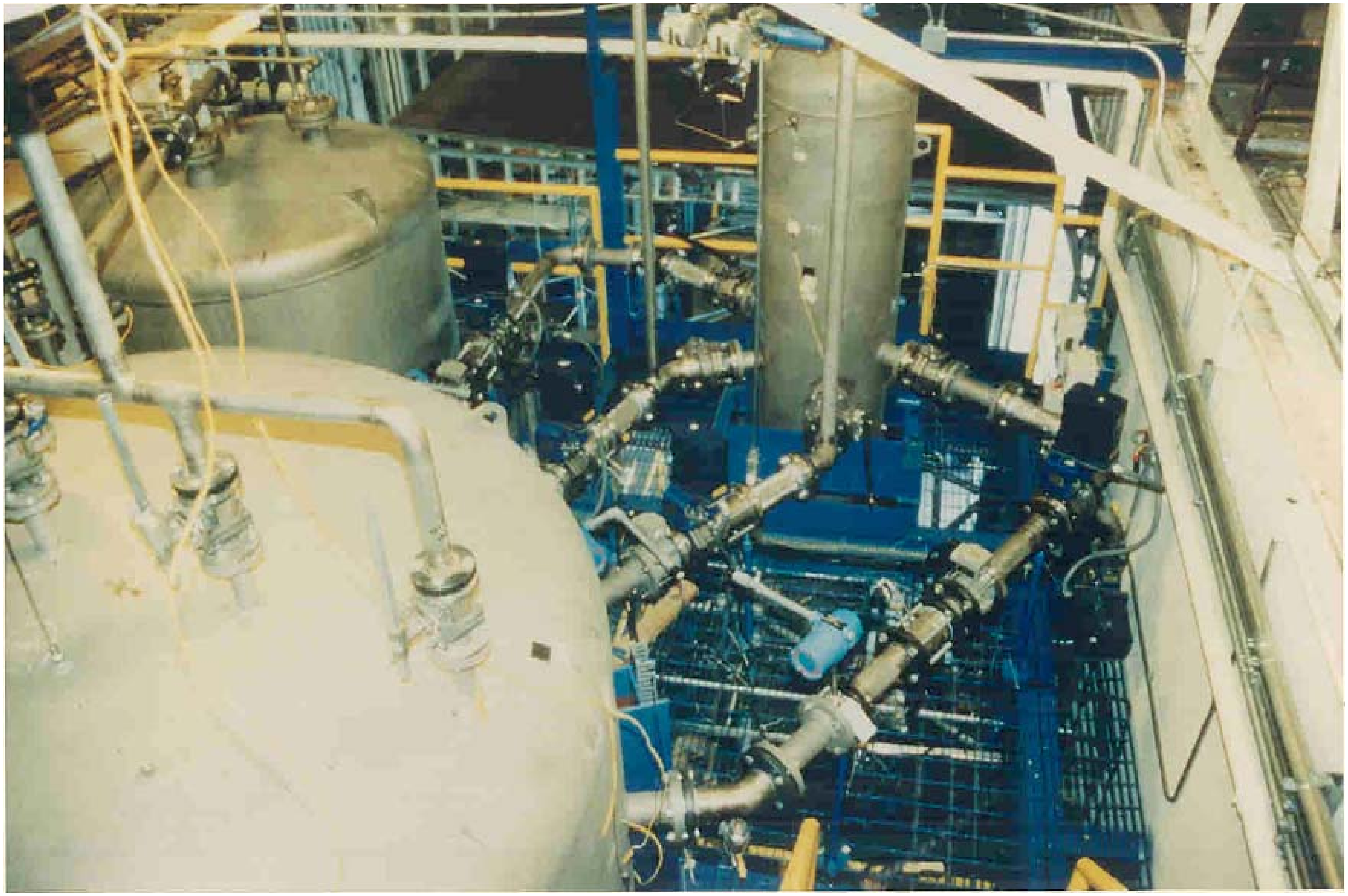
PUMA Facility



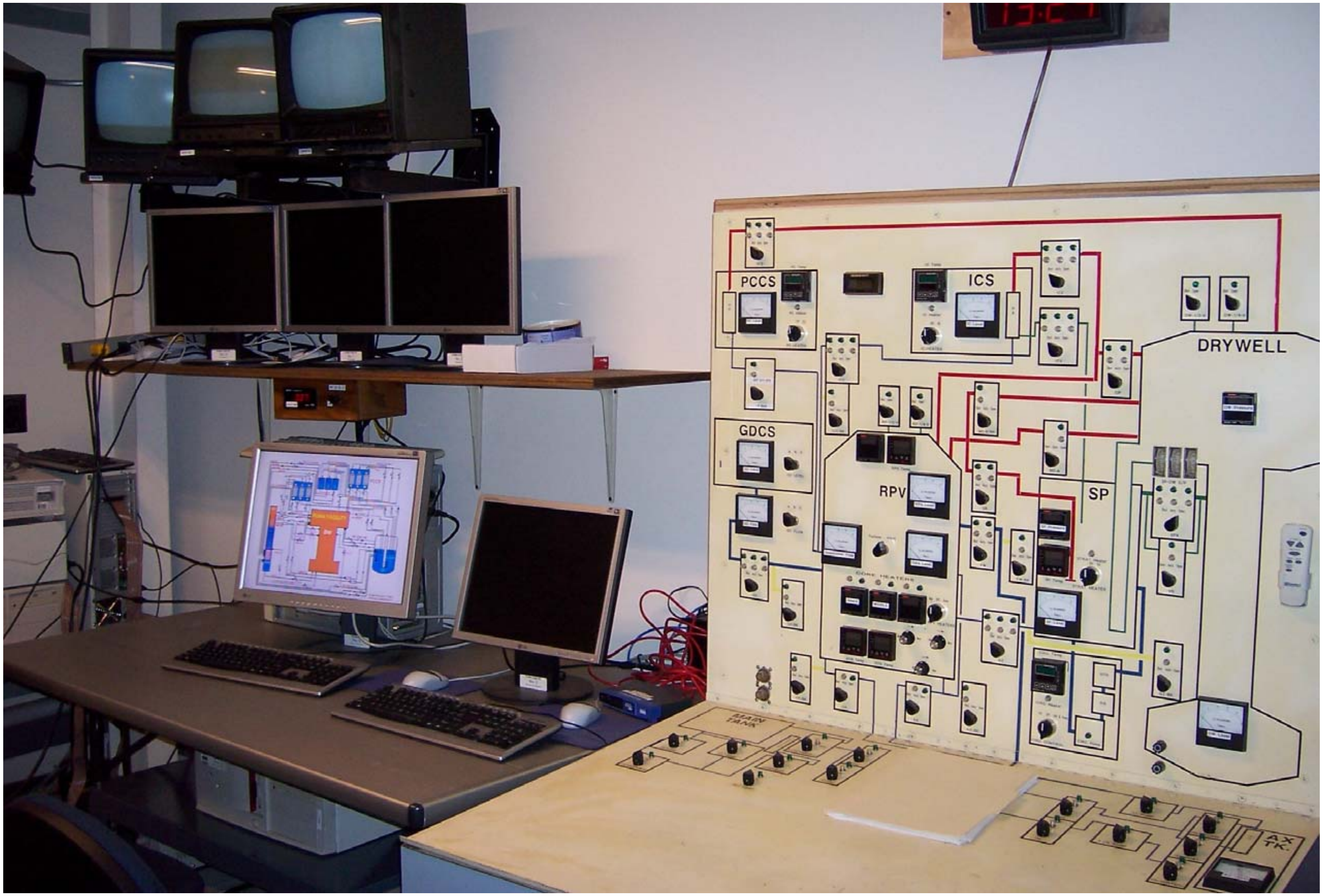
PUMA Facility (Front View)



PUMA Facility (Top View)



PUMA Facility (Control Room)

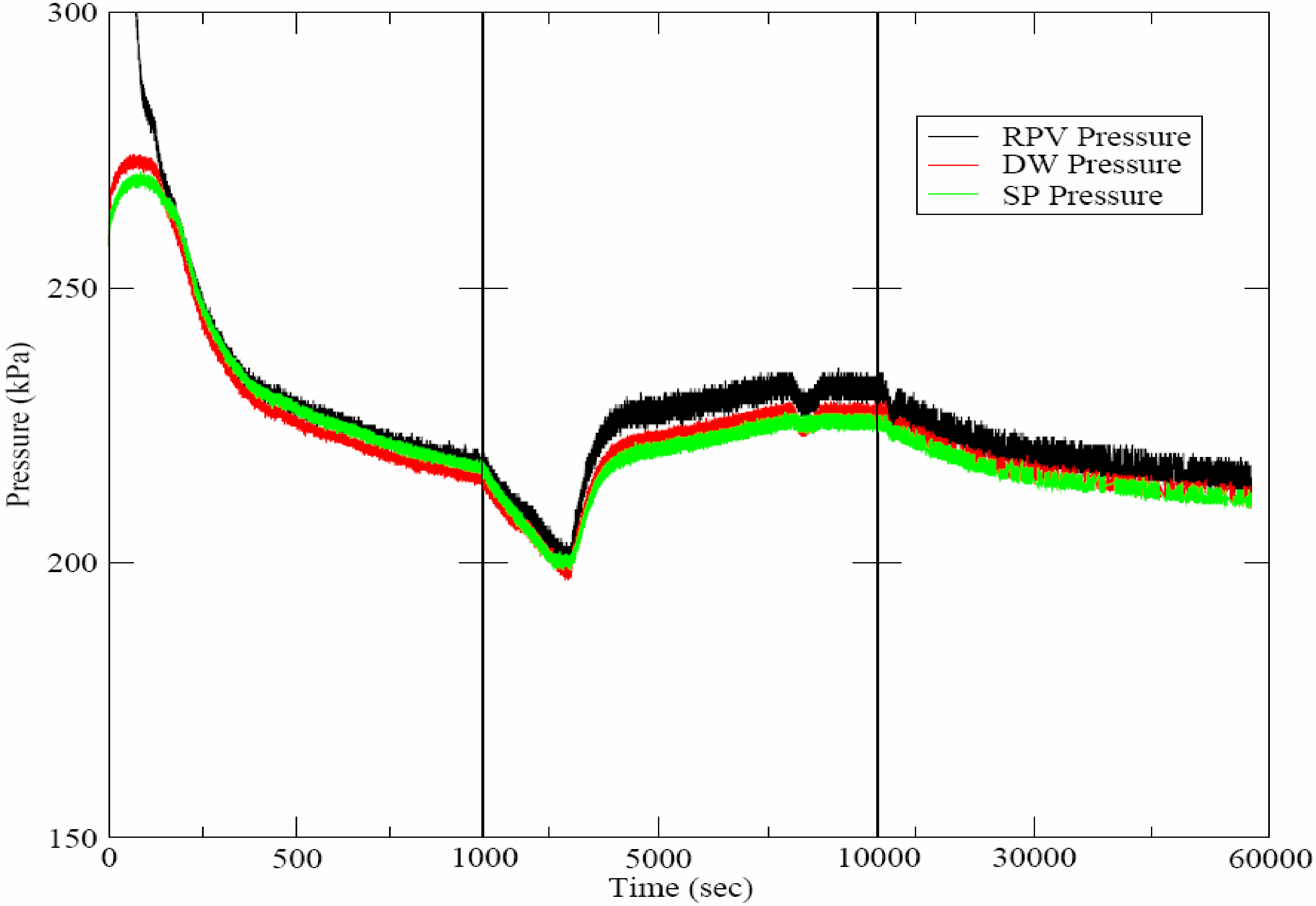


PUMA Integral Test
Bottom Drain Line Break (BDLB)

- Accident Scenario
  - Break size is small. It takes long time for reactor to reach Level 1.
  - Break location is low. Coolant is lost continuously until the pressure balance among RPV, Drywell and Wetwel is reached.
- Break Geometry
  - Break occurs at the junction of the bottom drain line and the reactor water cleanup unit line.

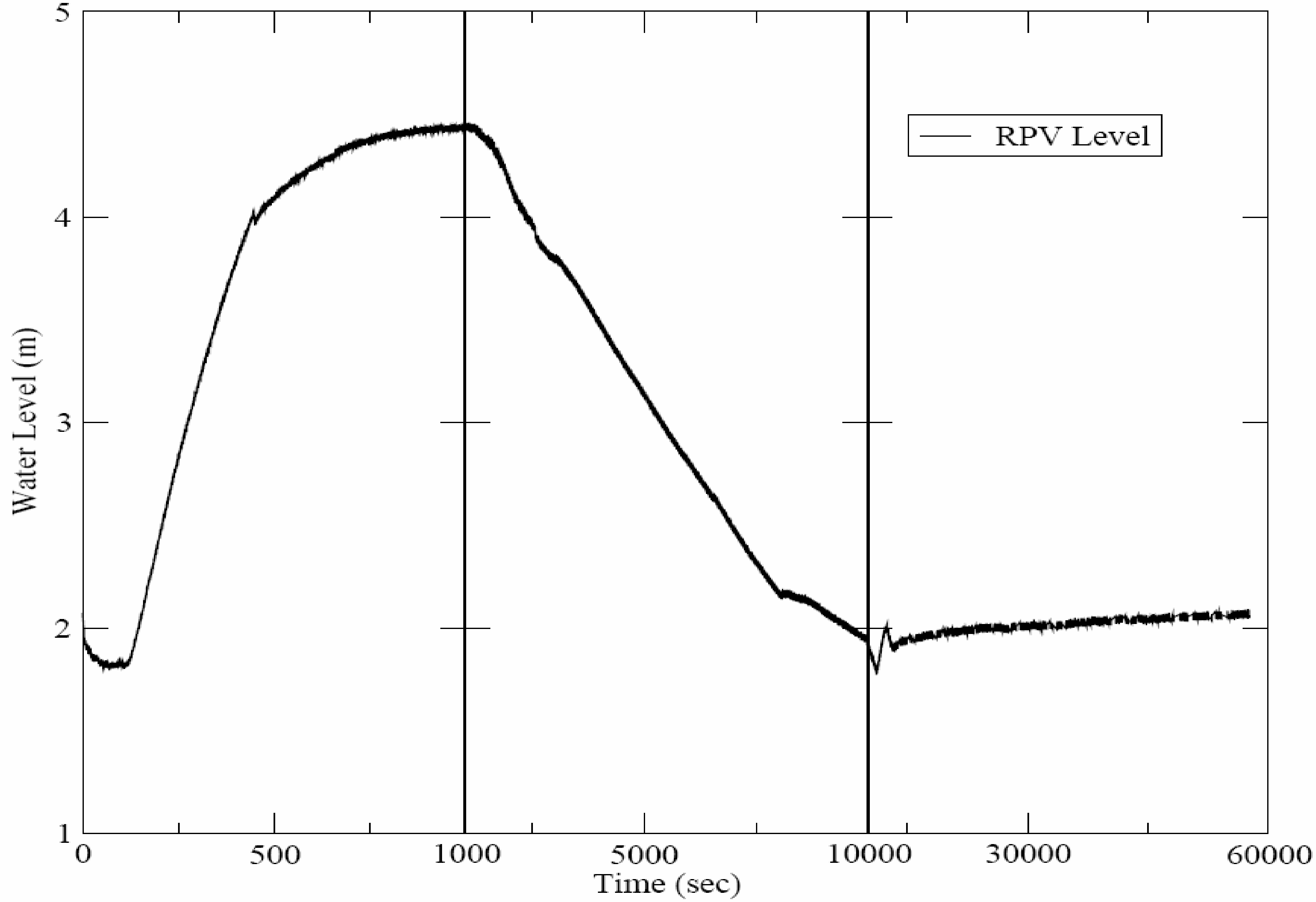
PUMA Integral Test Data (BDLB)

Pressure



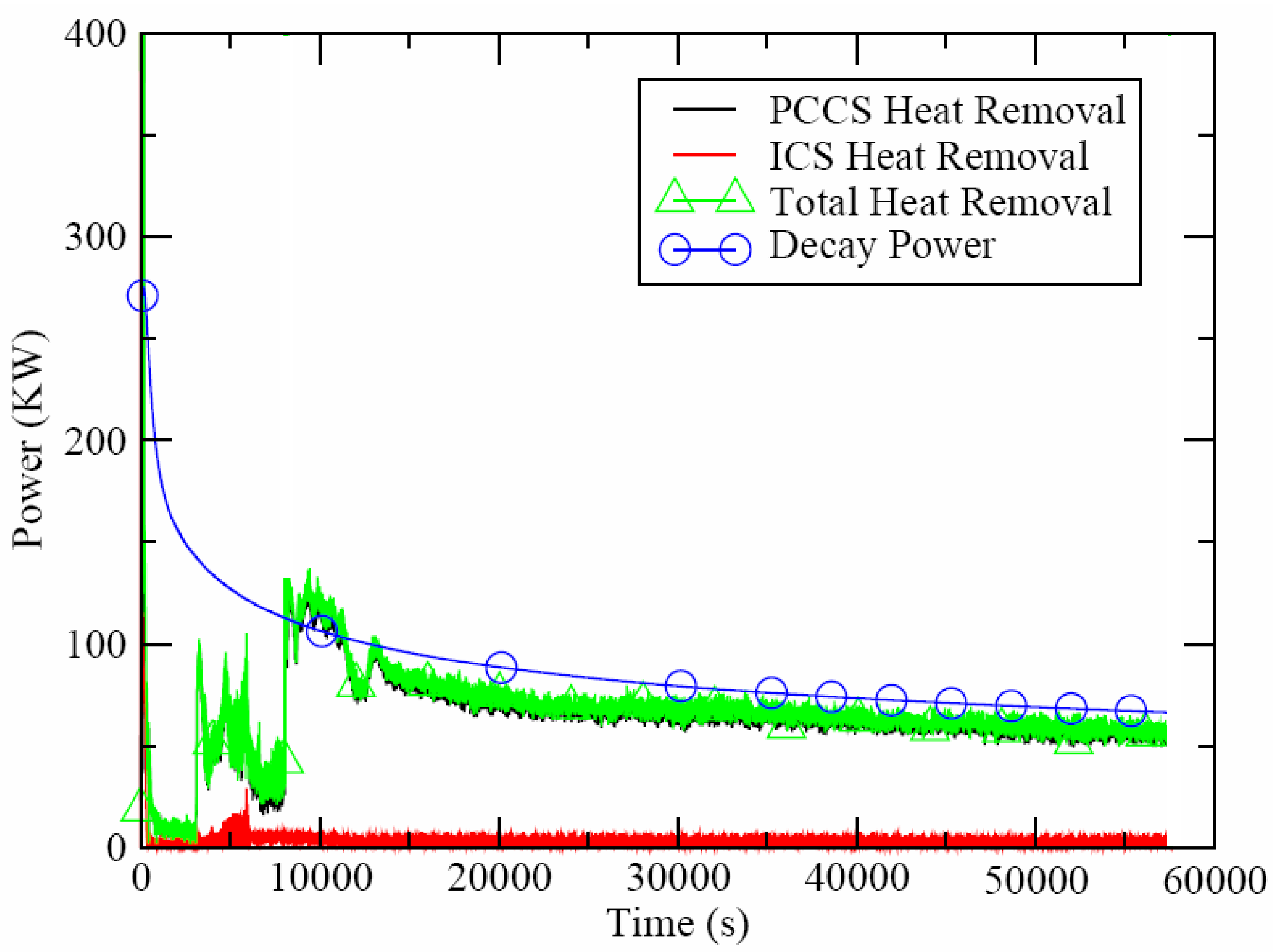
PUMA Integral Test Data (BDLB)

RPV Inventory



PUMA Integral Test Data (BDLB)

Decay Heat Removal



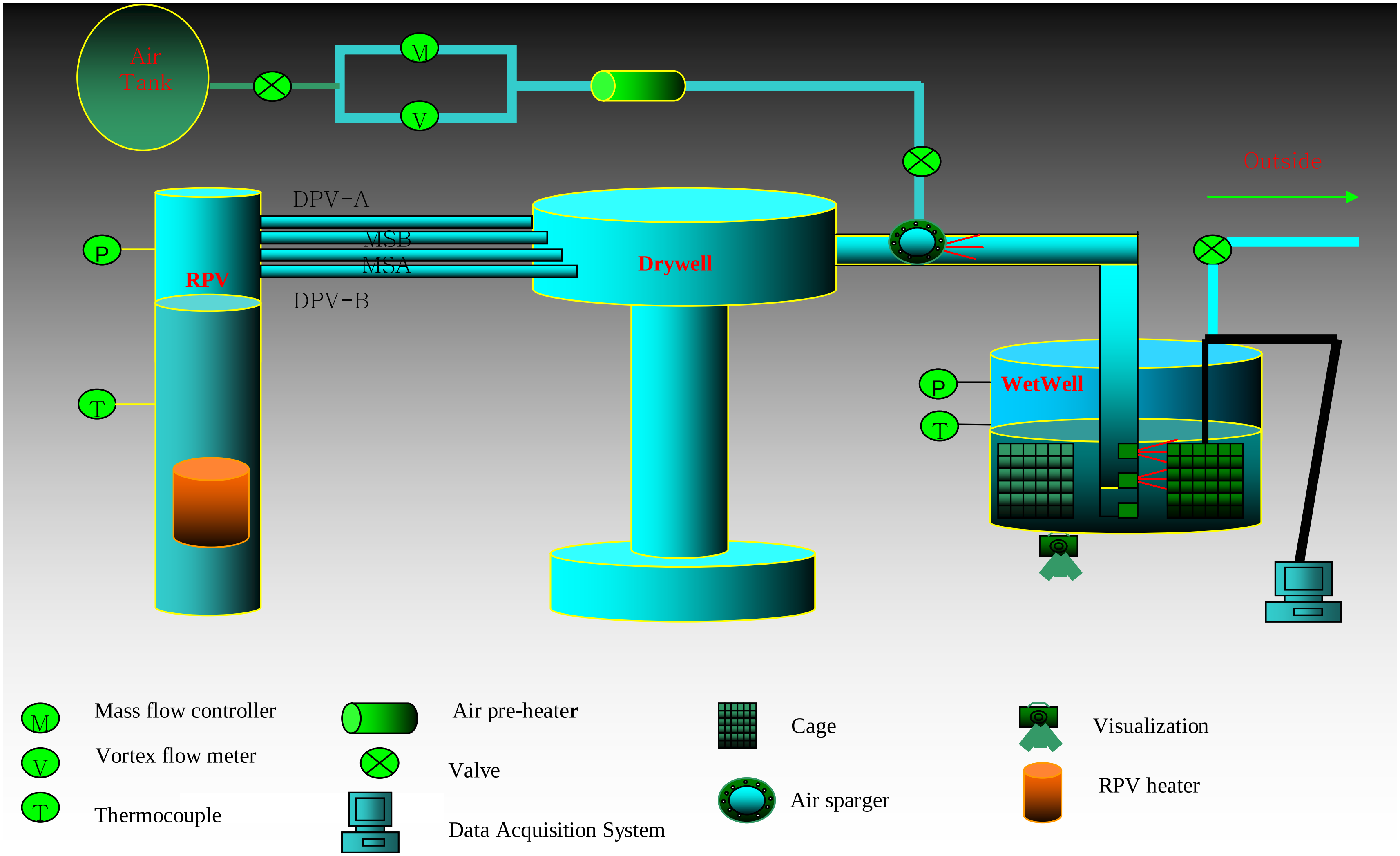
PUMA Separate Effects Test
Suppression Pool Mixing and Condensation

Objectives:

- Obtain the thermal stratification and mixing data
  - Noncondensable gas flow rate
  - Pool initial temperature
  - Steam mass flow rate
  - Submergence of vent opening
  - DW pressure
- Assess the effect of noncondensable gas flow rate on the pool mixing and thermal stratification
- Assess TRACE code modeling capability for thermal stratification in the suppression pool
- Improve the understanding of pool circulation driven by a bubble plume

PUMA Separate Effects Test

Suppression Pool Mixing and Condensation



PUMA Separate Effects Test
Suppression Pool Mixing and Condensation

Pool Circulation During Pure Steam Injection

- The convective circulation by the buoyancy force enables the pool above the heat source to circulate

- Steam injected from the vent is condensed at the exit and acts on the pool as a heat source.

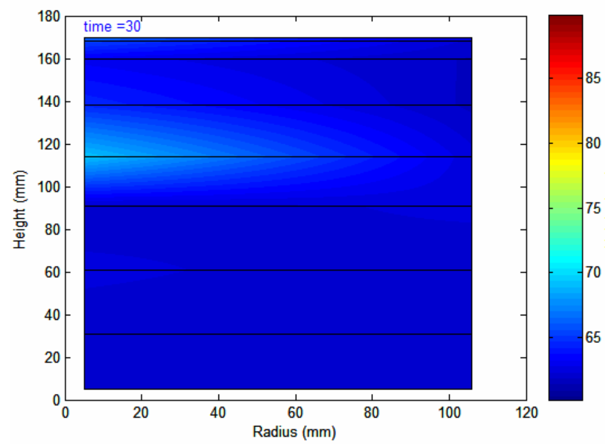
- Heat injected from the vent is accumulated in the volume of pool above the vent opening

PUMA Separate Effects Test

Suppression Pool Mixing and Condensation

Temperature profile (Vent direction, Pure steam)

Steam mass flow rate: 120 g/s, Initial pool temperature: 60°C, DW pressure: 230 kPa



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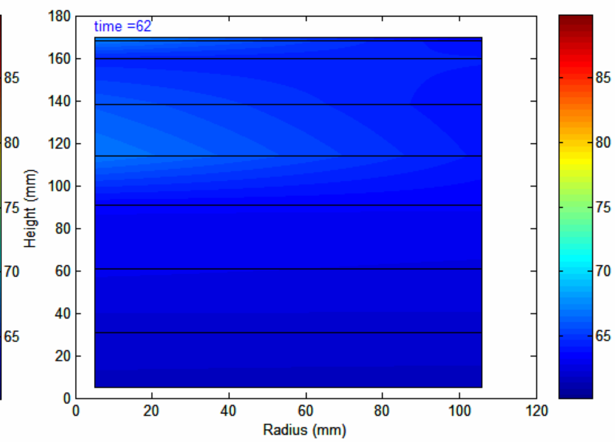

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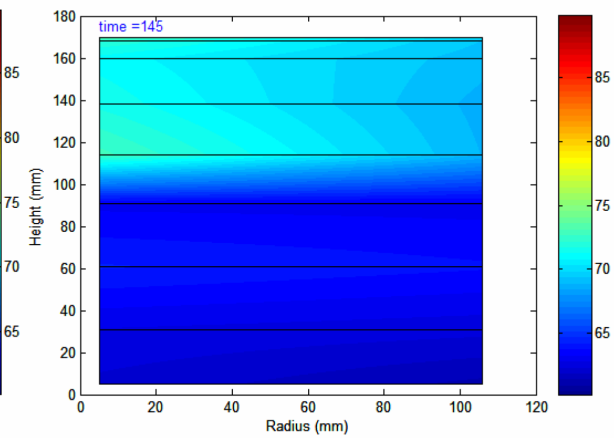

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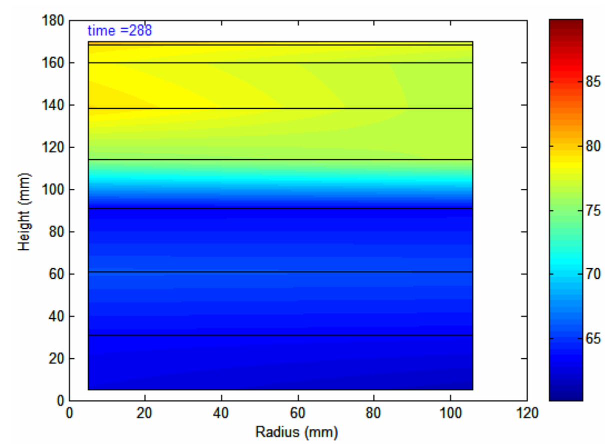

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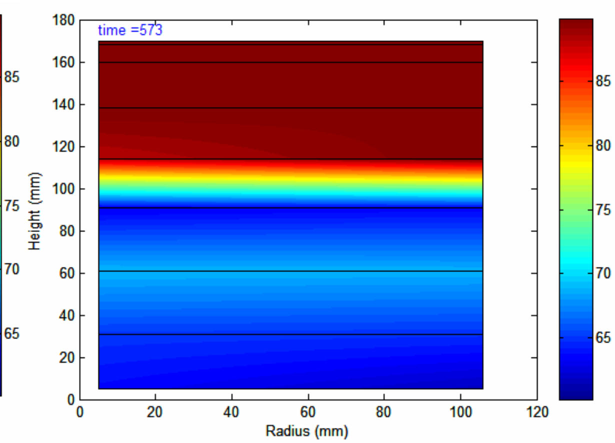

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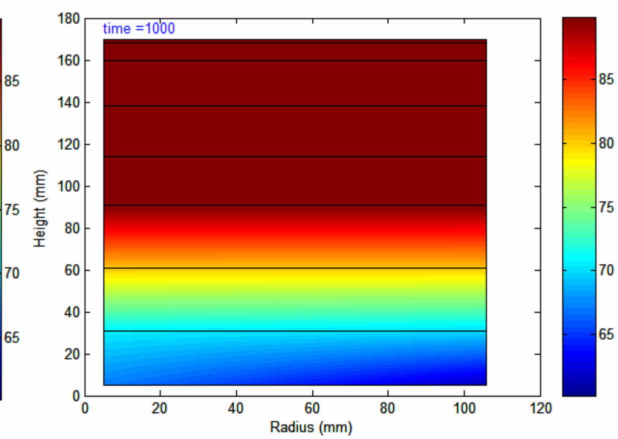

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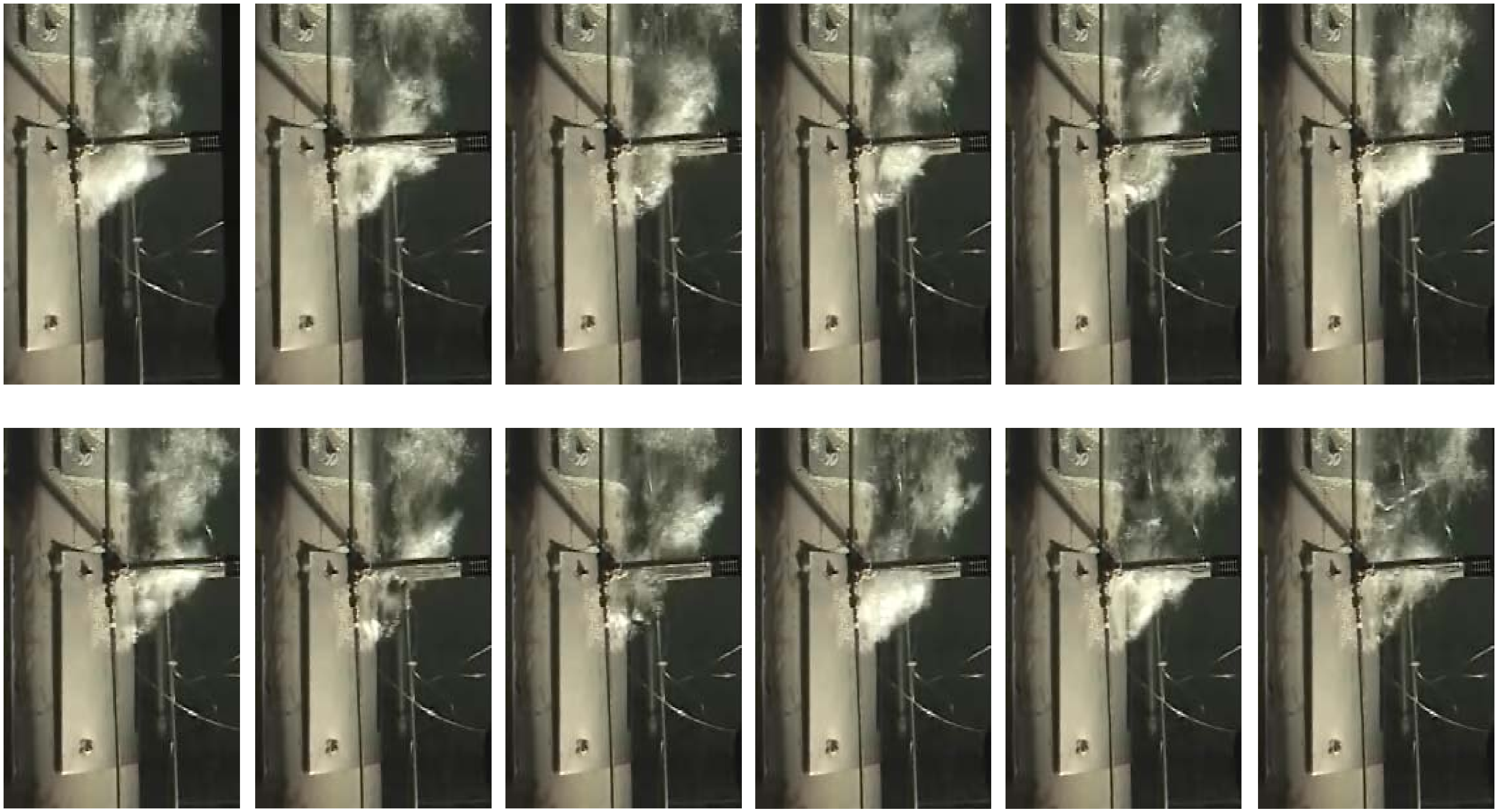
PUMA Separate Effects Test

Suppression Pool Mixing and Condensation

Digital Camcorder Image (1000 sec)

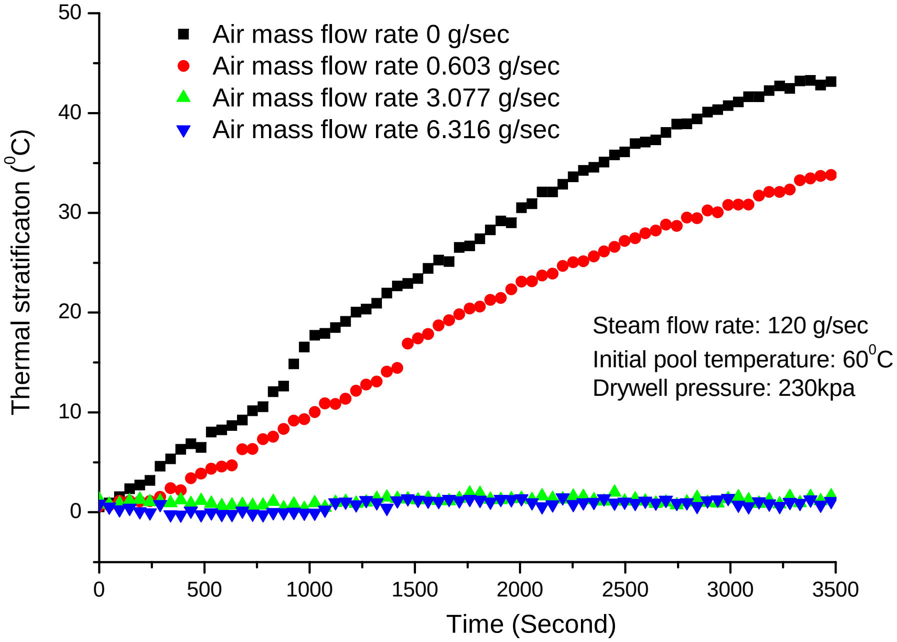


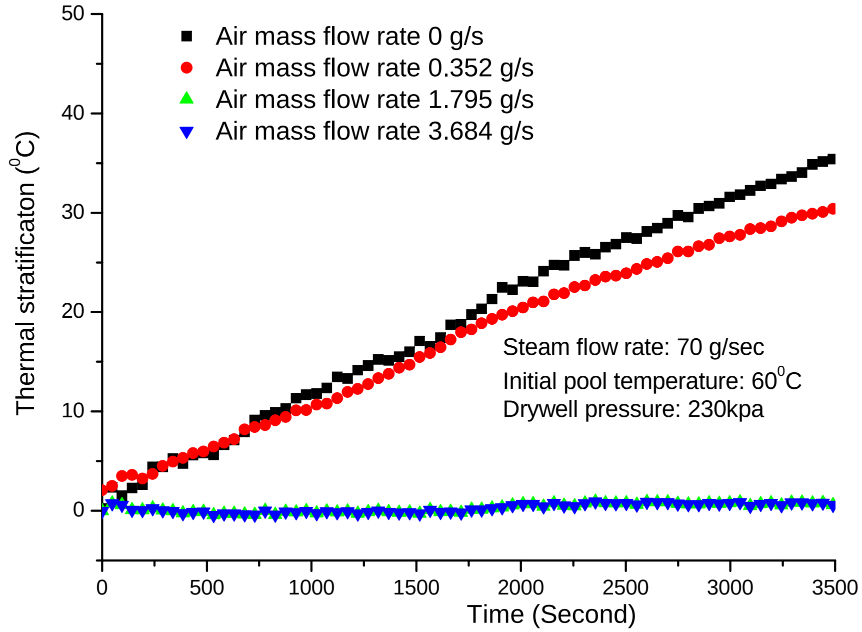
Digital camcorder images captured from injection of steam / air mixture at 120 g/s steam mass flow, 6.316 g/s noncondensable gas mass flow rate and 60˚C pool initial temperature (100 FPS)

PUMA Separate Effects Test

Suppression Pool Mixing and Condensation

Air Injection Flow Rate Effect on Thermal Stratification





Current Tasks

- Facility Modification
  Modified to Match Prototypic Conditions of
  Most Recent Advanced BWR Design

- Planned Integral Tests for
  Design Basis and Beyond Design Basis Accidents

- TRACE Code Assessment and Analysis of
  Bottom Drain Line Break LOCA Scenarios

Summary

- Initial PUMA Facility Built on Sound Scaling Method
- Simulate All Key Components and Safety Systems
- Capability for Design Basis Accident and Beyond Design Basis Accident Simulation
- Number of Integral Tests and Separate Effects Tests
- Started TRACE Code Verification
- New Tasks
  - Facility Modification
  - Integral Tests for DBA and Beyond DBA
  - TRACE Code Assessment